# DSIF *Mariner* Mars 1971 TCP Operational Program

R. L. Chafin
DSIF Operations Section

*The Deep Space Instrumentation Facility (DSIF) Mariner Mars 1971 Telemetry and Command Processing (TCP) Operational Program provides the software necessary to support the Mariner Mars 1971 mission operations by processing all telemetry data from the spacecraft and providing a means to command the spacecraft from both the Space Flight Operations Facility and the station. The program is designed for use with the multiple-mission telemetry and multiple-mission command hardware. This article describes the organization, operation, and capabilities of this program.*

## I. Introduction

The DSIF *Mariner* Mars 1971 TCP Operational Program (Fig. 1) was developed to provide on-site processing of telemetry and command data for support of the *Mariner* Mars 1971 Project. It was designed to be used with the MMT and MMC hardware.

## II. Program Description

The program is used in an XDS 920 computer with a 16,000-word core memory. The program was written with the objective of developing the telemetry and command sections separately. The telemetry and the command sections are combined in the same software package with an Executive. They were tested separately for functional integrity, then tested as a complete package for interference between sections.

### A. Executive

The executive program provides the basic framework for the *Mariner* Mars 1971 operations program. It controls the execution of the TLM and the CMD subprograms and controls the I/O activity. It also controls those functions which are common to both the TLM and the CMD programs, such as the HSD and the magnetic tape output.

This program operates under a real-time environment, which generates interrupts to interface with the system hardware. These interrupts generate flags to indicate routines needing servicing. The executive program sequentially polls the TLM and CMD subprogram flags and executes those subprograms needing servicing.

The HSD blocks, which are generated in the TLM and CMD programs, are buffered by the executive and

output on the HSD lines. The HSD blocks are grouped in 5-block records and recorded on magnetic tape for the Original Data Record (ODR).

The executive controls the I/O typewriter typeins and typeouts. On typeins, the executive inputs the typein statement, tests the first character for the desired destination, (i.e., TLM, CMD, or EXC) and transfers the message to the appropriate program. Typeins starting with T go to the channel 1 telemetry, D go to the channel 2 telemetry, C go to command, B goes to both, and E goes to the executive. The TLM and CMD programs provide the typeout message to the executive, which, in turn, outputs them on the I/O typewriter.

### B. Telemetry

The downlink transmitted by the spacecraft contains one or two telemetry data streams. During the cruise mission phase only one subcarrier is used, containing the engineering data. During the orbital mission phase a second subcarrier, containing the science data, is added. The station receiver locks up to the S-band carrier and provides the subcarriers to the SDA (Subcarrier Demodulator Assembly), one SDA to each subcarrier. The *Mariner* Mars 1971 TCP operations program processes each data stream separately. Channel 1 processes the engineering data and channel 2 processes the science data. The telemetry program frame syncs the engineering data and the low-rate science data and provides a TTY output as backup for the HSD output.

*1. Channel 1.* The channel 1 bit synchronizer consists of a combination of hardware and software. The integrated data stream from the SDA is sampled by the ADC (Analog to Digital Converter). The channel 1 subprogram makes an estimate of the bit transitions, calculates an error from the input data, and outputs a correction term to the numerical controlled oscillator. In terms of a phase-locked loop, the software provides the error detector and the filter; the numerical controlled oscillator is the VCO. The channel 1 telemetry program determines the logic value and the time of the incoming data and accumulates a digital data stream with appropriate time tags. The data is formatted into HSD blocks for outputting and recording. The analog data values are accumulated and processed to obtain an estimate of the SNR (signal-to-noise ratio).

*2. Channel 2.* The channel 2 bit synchronization is accomplished in the SSA (Symbol Synchronizer Assembly). For uncoded science telemetry, the data is input to the channel 2 program as a parallel digital number of 24 bits. For block-coded telemetry, that digital symbol data from the SSA is transferred to the BDA (Block Decoder Assembly) for decoding. The digital output from the BDA is input to the channel 2 program in a parallel 24-bit format. The channel 2 program formats the data into HSD blocks for outputting and recording. Data statistics are accumulated in the SSA and BDA. These statistics are input to the channel 2 program and are used to obtain estimates of the SNR for the telemetry stream.

*3. Frame sync.* Frame sync is obtained on the engineering data and the low-rate science data, using the PN bit sequence which is part of the *Mariner* Mars 1971 telemetry format. The engineering data stream is fully decommutated. The low-rate science is partially decommutated with pre-selected data parameters available for TTY output.

### C. Command

The command program receives spacecraft commands from the SFOF by HSD, stores the commands, and outputs the commands to the CMA (Command Modulation Assembly). The CMA forms the command signal from the subcarrier frequency modulated by the command data and a PN sync signal.

*1. Modulation index control.* The command signal modulation index is controlled by the command program. The level of the command signal, which determines the modulation index, is controlled by a digital attenuator, and is set by the program.

*2. Configuration control.* The CMA configurations are stored in the configuration table. There is one configuration table entry for each mode. When a mode is entered, the appropriate configuration word is sent to the CMA. There it sets the relays, which generate the desired configuration. The configuration table can be modified by HSD input or by manual I/O input. The program provides an output of the contents of the configuration table upon either HSD or operator request.

*3. Command stack.* The stored commands are contained in the command stack. The program receives commands by either HSD input from the SFOF or by manual I/O entry. Commands are either *timed* commands or *priority* commands. Each new command is placed in the command stack following the preceding commands. *Priority* commands are output when they are

enabled. A series of enabled *priority* commands will be queued and output according to their entry into the command stack. Enabled *timed* commands will be output according to the transmission time associated with the command.

The program will provide a recall of the command stack upon request. The recall can be either by HSD or by manual I/O request. The recall response output, for an HSD request, is by HSD, for an I/O request it is by local RO display.

The status of the command stack is monitored and appropriate warning alarms are generated when the stack is near full, full, or contains commands which should be transmitted, but cannot be transmitted for some reason. When a particular command has been successfully transmitted, an HSD command confirmation message is output to the SFOF and the command is removed from the command stack.

*4. System check.* During the operation of the command program, the status of the station command system is continually checked. The parameters being checked are: transmitter ON, CMD modulation ON, correct exciter channel, and correct subcarrier frequency and bit rate. Discovery of any of these parameter outside their limits or in an incorrect state produces an alarm. The alarm message is sent to the SFOF by HSD and also displayed on the local RO display.

*5. Commanding checks.* During the time a command is being clocked out, the same system checks are being made. An anomalous system condition aborts the outgoing command. An abort HSD message is sent to the SFOF. The abort message contains the command that was attempted, the reason for the abort, and the bit on which the command was aborted.

The outgoing command signal is monitored by the command program. The subcarrier level and the PN sync level are checked each bit time. The outgoing command signal is demodulated and checked bit by bit against the command, which was intended to be sent. Any failure produces an abort.

*6. Standard and limits tables.* The limits of the parameters, which are checked during the system and commanding checks, are stored in the standards and limits tables. The table contains canned-in nominal limits. These limits can be modified by either HSD or manual I/O inputs. The contents of the table can be reviewed by means of a recall request. Again, the response to a recall request can be either HSD output or local RO output.

*7. Incoming HSD message processing.* The incoming HSD blocks are checked for a GCF error indication. They are also checked for proper station ID and spacecraft ID. If all checks are passed, the block is returned to the SFOF as a verification that the HSD block was received and the data in the block is routed to the proper destination. If the checks are not passed, an appropriate alarm is generated (placed in the verification message), which is sent to the SFOF. Rejection of the incoming HSD block by the command program is indicated by a specific bit in the alarm code included in the verification message. In this case, the verification message indicates that the original message was received by the command program, but was not acted upon because of an error in the format.

## III. Operation

### A. Initialization

There are a very large number of parameters required by the *Mariner* Mars 1971 operations program. In order to simplify the operation of the program, standard configurations and operating conditions were selected and canned into the program. A simplified initialization was designed for nominal operations. Capability of modifying the standard configuration is included in the design in order to accommodate nonstandard conditions. The nominal or standard telemetry initialization typeins are keyed to the different nominal mission phases:

| | | |
|---|---|---|
| Cruise | DCH/XX,Y,ZZ$ | 33⅓ bps engineering data |
| Orbital | DOL/XX,Y,ZZ$ | 8⅓ bps engineering data, 50 bps uncoded science data |
| | DOH/XX,Y,ZZ$ | 33⅓ bps engineering data, 50 bps uncoded science data |
| | DSD/XX,Y,ZZ$ | 8.1 kbps block coded spectral science data |
| | DTV/XX,Y,ZZ$ | 16.2 kbps block coded recorded science data |

where

XX = the station number

Y = the TCP computer being used

ZZ = the spacecraft number

$ = the typein terminator

In the simplest configuration, the above typein is all that is required to initialize the telemetry program. For normal operations, one more typein is required to input the AGC calibration data for the AGC (voltage) to signal level (dBm) conversion. The telemetry program is started with the typein TRUN$. On starting, the telemetry program acquires the telemetry data streams and initiates the HSD output and the ODR recording.

The command program is initialized with the typein

CSS/XX,Y,ZZ$

This typein identifies the station number, computer, and spacecraft number to the command program.

The command signal modulation index is measured by station instrumentation and adjusted with a typein instruction. The command program is started with the typein CRUN$. The normal command operation is controlled remotely by HSD from the SFOF. Local manual control is available as a backup.

Nonstandard typeins are available to change the telemetry system configurations. For example, TS1/1,2,2$ modifies the channel 1 configuration to Receiver 1, SDA 2, computer B. Other telemetry bit rates are available, such as 1.0125, 2.025, 4.05, 8.1, 16.2 kbps, etc.; TB 2/10 is an example selecting 1.0125 kbps for telemetry channel 2. The bit loop SSA and BDA parameters, such as bandwidth, are canned in for each bit rate, but can be modified by nonstandard typeins.

Nominal configurations and parameters are canned in the program. Normal operation is to control the configurations and standard and limits parameters by HSD from the SFOF. However, nonstandard typeins are available to change these items at the station manually.

The HSD and ODR magnetic tape recording functions are normally enabled so that no operator action is required to initiate these functions. Typeins are available to control these activities. Each telemetry channel (i.e., 1 or 2) or command can be controlled separately or both together.

For example,

BHS/D$ disables all HSD output

CHS/D$ disables only command output

THS/D$ disables only channel 1 telemetry

DHS/D$ disables only channel 2 telemetry

The TTY output is not normally enabled. There is a complete set of typein statements that control the TTY output and the generation of headers.

### B. Operation Modes

There are two telemetry modes, operating and initialization. The telemetry program processes the telemetry data during the operating mode. The processing is stopped during the initialization (or reinitialization) mode. During initialization typein statements are accepted to modify configurations, bit rates, etc. During the operating modes these input requests are ignored. The operating mode is initiated with a TRUN$ typein. Reinitialization is requested with typeins which stop the processing of the selected telemetry channel.

For example,

DIN/$ stops both telemetry channels

DIN1$ stops channel 1

DIN2$ stops channel 2

The command modes are more involved. They can be described as follows:

*Calibrate 1.* This mode is entered at the start of operations and is used to adjust the modulation index of the command signal.

*Calibrate 2.* This mode outputs parameters to the CMA. For example, going to CAL 2 mode allows a new subcarrier frequency to be sent to the CMA. Also, this mode is used when no commanding is anticipated, as when the station has no uplink.

*IDLE 1.* This is an idle mode where the spacecraft command loop is locked but no commanding can be accomplished. The system checks are made and alarms generated.

*IDLE 2.* This is the mode used when the station is in a commanding period but is between commands. System checks are made and alarms generated. The command system is ready to transmit commands.

*Active.* This is the mode used when a command is being transmitted. System check and command sig-

nal checks are made, and if any anomaly is detected, the command is aborted.

*Abort.* This mode is entered when a command is aborted. The PN sync code is inverted for 2 seconds to signal the spacecraft to inhibit that command, and 28 zeros are sent.

Figure 2 illustrates the mode sequence for the command program. The station brings the program to the CAL 1 mode and sets up the modulation index. After CRUN$ is entered by the station, the SFOF controls the mode by HSD. The command system is taken through CAL 2 and IDLE 1 and is ready for commanding. When a command is available for transmission, the program goes to active and transmits the command. The return is to IDLE 2 for a successfully completed command. The abort mode is entered directly from the active mode, upon detection of an anomaly. After the abort mode is completed, the program reverts to the mode specified in the abort return address. This will normally be IDLE 1. If IDLE 1 is the abort return mode, then no further commanding can be accomplished until action is taken to place the program in IDLE 2.

### C. Manual Operation

The telemetry program is completely under manual station control. Normally the only action required is during initialization. In the operating mode the operation of the program is automatic.

The command program is normally operated remotely from the SFOF. In order to provide a backup capability in the event that communications are lost with the SFOF, a manual operating capability is included. The manual capability is normally locked out with a key-operated switch on the station manger's console. When manual operations is selected, the command program can be controlled locally. Commands can be entered into the command stack, enabled, and transmitted. The command system modes can be controlled by I/O typeins and commands can be aborted by operator initiative.

### D. Performance Monitoring

The performance of the telemetry system is monitored with the estimated SNR produced by the program, the lock status information obtained from the receiver, SDA, bit loop, SSA and BDA, and from the received signal level obtained from the receiver AGC. This information is packed into the HSD blocks and is transmitted along with the telemetry data. The lock status information is also output with the TTY data.

The performance of the command system is monitored by the station personnel with a teleprinter (RO) output. The RO presents the significant command activity (such as commands entering the command stack and commands transmitted). Also the RO allows the operator visibility into the contents of the command stack, configuration cable, and the standards and limits table.

The previously described performance data, together with the telemetry and command program activity status, is sent to the station monitoring program in the digital instrumentation system (DIS) computer by means of a direct computer-to-computer link. The station monitor program displays the data on a CRT display for the station manager and sends the data to the SFOF as a part of the DSN Monitor System.

### E. Inputs

The inputs to the telemetry program are the two telemetry data streams and the I/O initialization. The telemetry data streams are:

Channel 1 Engineering data, uncoded either 8⅓ or 33⅓ bps.

Channel 2 Science data, one of the following:

(a) Coded 50 bps.

(b) Block coded 1.0125, 2.025, 4.05, 8.1, 16.2 kbps. Recorded science, selected video, or spectral science.

The inputs to the command program are the I/O initialization, HSD messages from the SFOF, and manual operating I/O inputs. The HSD messages are:

| | |
|---|---|
| Command | Contains up to 8 new commands. |
| Enable/disable | Enables or disables a command in the command stack. |
| Configuration | Modifies the configuration table. |
| Standards and limits | Modifies the standards and limits table. |
| Recall request | Requests recall of either the command stack, the configuration table, or the standards and limits table. |

### F. Outputs

The output of the telemetry program consists of HSD blocks. There are two telemetry formats. The engineering data and the low-rate science data HSD blocks contain 168 bits in each block. The higher-rate science data HSD

blocks contain 936 bits. The time to accumulate data from the spacecraft to fill up one HSD block is as follows:

| Data rate, bps | Time to accumulate data, s | Bits per HSD block |
|---|---|---|
| 8⅓ | 20.16 | 168 |
| 33⅓ | 5.04 | 168 |
| 50 | 3.36 | 168 |
| 1012.5 | 0.924 | 936 |
| 2025 | 0.462 | 936 |
| 4050 | 0.231 | 936 |
| 8100 | 0.1155 | 936 |
| 16200 | 0.05775 | 936 |

The HSD blocks consist of 1200 bits of header, data, overhead, and filler. The HSD operates at a rate of 4800 bps; therefore, a block is output every 0.25 s. From the above table it can be seen that only 2025-bps data and under can be sent by HSD. All higher data rates must use a wide-band (WB) line, which is only available between DSS 14 and the SFOF. The WB line operates at 50 kbps and is capable of transmitting a block every 0.024 s.

The output of the command program is the command data stream and the HSD messages, which report command activity to the SFOF. These messages are:

Confirm/abort — Reports the successful transmission of a command (confirm) or an unsuccessful transmission (abort).

Alarms — Detection of an anomalous system condition generates an alarm message containing a code indicating the cause of the alarm.

Recall response — A recall request will generate a message or series of messages in response. They will contain the contents of the command stack, the configuration table, or the standards and limits table as requested.

Verification — Every received HSD message is turned around and sent back as a verification that the block is received. Any alarms generated by the message or any outstanding alarms are added to the verification message.

All HSD blocks, both incoming and outgoing, are recorded on magnetic tape as an Original Data Record (ODR). All manual inputs are formatted into equivalent HSD records and also recorded on the ODR.

The backup TTY outputs data in three formats.

(1) 8⅓ or 33⅓ bps engineering data only.

(2) 50 bps science data only.

(3) 8⅓ and 50 bps data confined.

Only one TTY line is required for each of these data formats.

## IV. Conclusion

The *Mariner* Mars 1971 TCP Operational Program provides the software necessary to support the *Mariner* Mars 1971 mission operations by processing all telemetry data from the spacecraft and providing a means to command the spacecraft from both the SFOF and the station.

## Bibliography


Chafin, R. L., et al., "Mariner Mars 1971 TCP Operational Program," Document 610-141, Oct. 1, 1970 (JPL internal document).

Chafin, R. L., and Carter, R. D., "Software Requirements Document Mariner Mars 1971 TCP Operational Program," DSN Software Design Book DSW-2-6000-M71, Sept. 15, 1970 (JPL internal document).

Crow, R., et al., "DSIF Multiple Mission Command System," in *The Deep Space Network*, Space Programs Summary 37-63, Vol. II, pp. 77–94. Jet Propulsion Laboratory, Pasadena, Calif., May 31, 1970.

Frey, W., et al., "Multiple Mission Telemetry 1971 Configuration," in *The Deep Space Network*, Space Programs Summary 37-63, Vol. II, pp. 63–77. Jet Propulsion Laboratory, Pasadena, Calif., May 31, 1970.

Kinder, W. J., and Gatz, E. C., "Telemetry System," in *The Deep Space Network*, Space Programs Summary 37-58, Vol. II, pp. 3–11. Jet Propulsion Laboratory, Pasadena, Calif., July 31, 1969.

Kinder, W. J., "Multiple-Mission Command and Telemetry Systems High-Speed and Wide Band Data Formats," in *The Deep Space Network*, Space Programs Summary 37-62, Vol. II, pp. 3–5. Jet Propulsion Laboratory, Pasadena, Calif., Mar. 31, 1970.

Rakunas, R. R., and Schulze, A., "DSN Multiple-Mission Command System," in *The Deep Space Network Progress Report*, Technical Report 32-1526, Vol. III, pp. 4–6. Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1971.

Wilcher, J. H., et al., "DSIF Multiple-Mission Command System," in *The Deep Space Network*, Space Programs Summary 37-59, Vol. II, pp. 119–139. Jet Propulsion Laboratory, Pasadena, Calif., Sept. 30, 1969.

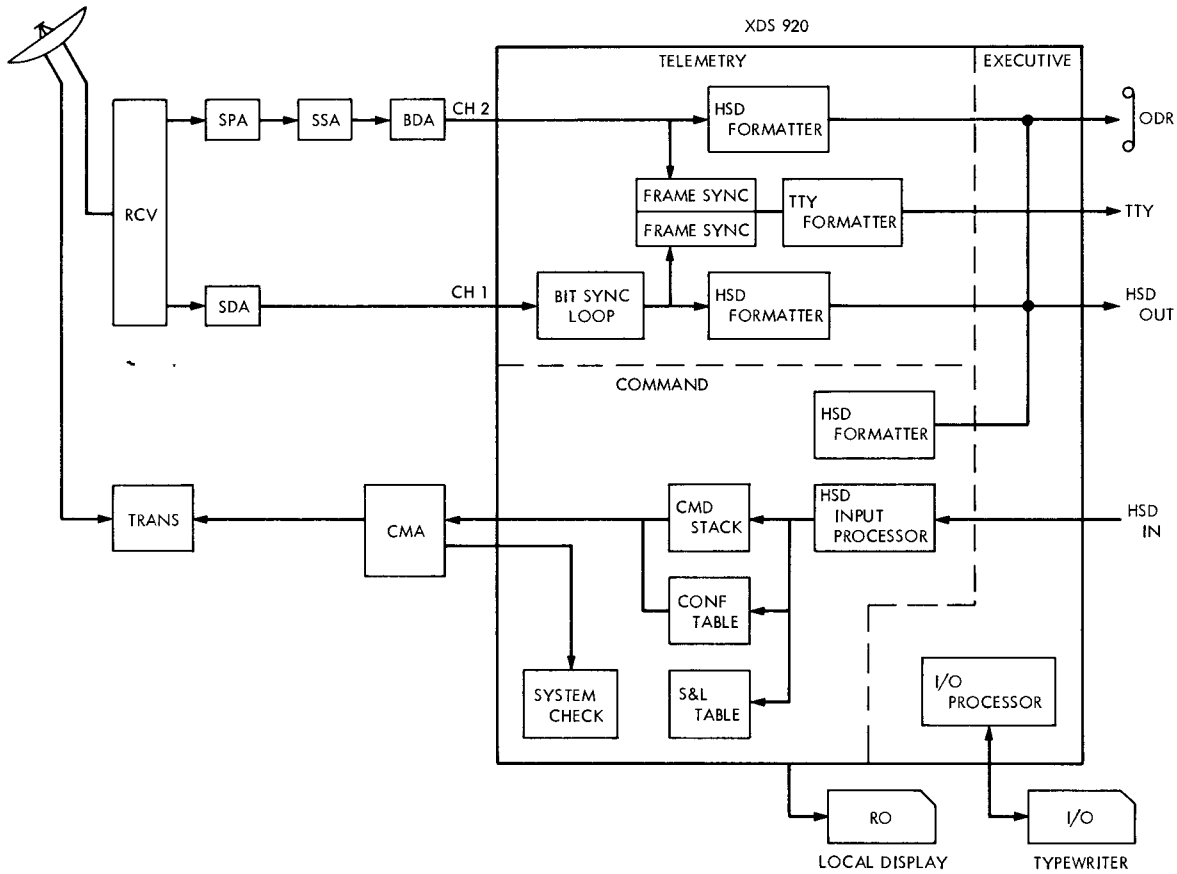


**Fig. 1. *Mariner* Mars 1971 TCP Operational Program**

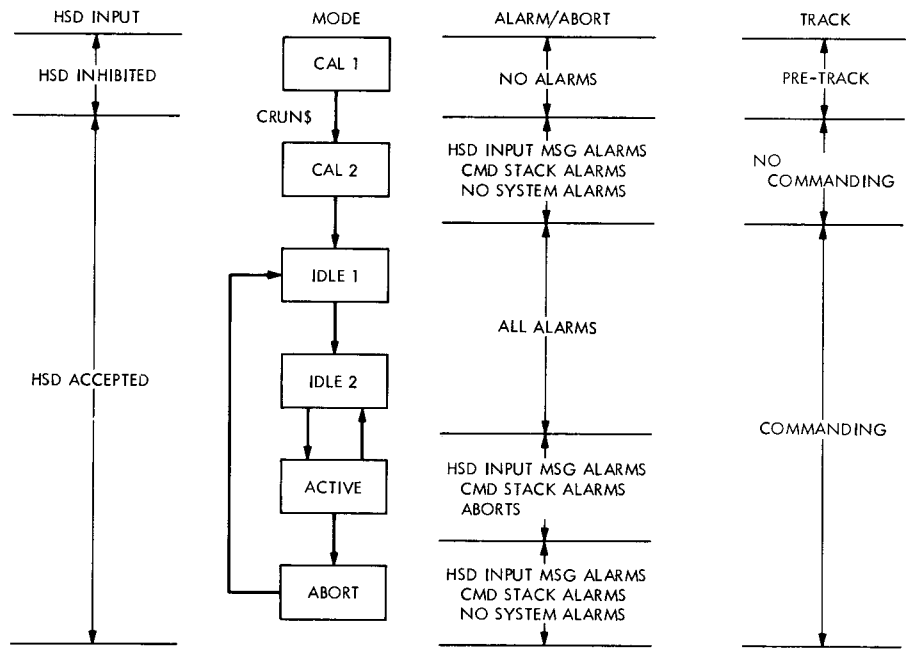


**Fig. 2. *Mariner* Mars 1971 TCP Command Program**